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FOR MINERAL EXPLORATION

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THE TECHNIQUE OF PHOTO-INTERPRETATION FOR MINERAL EXPLORATION

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The geological interpretation of aerial photographs is an important aid in the search for minerals. This method of exploration, therefore, is used in an increasing number of countries and the related techniques are rapidly developing. Photo interpretation has proved its usefulness for mineral exploration in almost every type of terrain, irrespective of the relief, the soil and vegetation cover and the intensity of the land use. The amount of detail that can be obtained varies greatly from one area to another, but everywhere the method has contributed so much to the efficiency of mineral exploration, and thus to the lowering of the cost involved, that a modern exploration project without an elaborate photogeological programme is not warranted.

Mineral Reconnaissance.

Systematic geological reconnaissance is the only sound starting point for a mineral resources inventory. Proper selection of areas of possible economic geological interest is only possible if sufficient data of the regional geology are available. Geological mapping by the conventional field methods, however, is very costly and the area that can be mapped per annum by an average geologist is only limited. Photogeological procedures reduce the amount of necessary field work and thus result in considerable savings. Even more important is the considerable increase in the area that can be mapped per annum and per geologist. The greater accuracy and the substantial amount of additional detail obtained in many areas by photogeological means are a third advantage of the method. For these reasons it is evident that aerial photograph interpretation is one of the important means of coping with the necessity of rapid development of mineral resources in the developing countries.

Adequate coordination of field investigations and the photo-geological studies is an essential prerequisite for obtaining satisfactory results in this first phase of mineral exploration. The customary procedure is to carry out photogeological studies and to prepare a preliminary photo-geological map of the area concerned prior to the field work. The geol-

ogical information existing, such as maps, reports and descriptions of rock samples, is consulted in order to obtain the most reliable results. The areas adjacent to the one under consideration are often included in the study, as there may exist some detailed field data, pertinent to these regions, which may prove most valuable for the correct interpretation of the area studied. Such extrapolation is common practice in photogeology. Another advantage of the inclusion of adjacent areas in the preliminary photogeological studies is that they allow for an understanding of the regional lithological and structural relationships.

The obvious advantages of the preliminary photo interpretation are, amongst others, that the areas of possible economic interest can be selected where subsequent detailed field and air photo studies should be carried out. Extensive areas of little promise can often be indicated where there is no immediate need for carrying out - often expensive - field surveys. All efforts can thus be concentrated on those areas where economic results are more likely. It may even be that phenomena or anomalies are observed on the air photos indicating the occurrence of ore deposits of possible economic interest. It should be borne in mind, however, that this is rather exceptional, that normally the finding of such deposits results from a thorough evaluation of the regional geological studies. Another, not less important advantage of the preliminary interpretation phase is for the planning of the actual field trip. The routes of traverses can be chosen in such a way as to yield a maximum of geological information and a minimum of terrain difficulties. The number of field days is thus kept to a minimum.

Geological photo interpretation has two distinct aspects, viz. the delineation, on the one hand, of boundaries of the various rock formations occurring and on the other the lithological interpretation. The topographical expression of the rock types and formations is the most important indicator for the plotting of these boundaries, because the terrain configuration is the most conspicuous feature to be seen on the air photos. Geomorphology has thus a central position in photogeology. Items of particular interest are, for instance, the pattern and density of the drainage, the cross-sections of valleys and gullies, etc. Vegetation, grey tone and also land use are among other indications which are among other indications which are usually of secondary importance. The lithological interpretation is often fraught with difficulties especially if little or no field information is available and if the photo interpreter has little experience with the type of terrain concerned. In some difficult areas where only a few scattered outcrops occur due to the dense soil and vegetation cover, it may only be possible to delineate areas of similar morphological outlook, so-called photogeological units, without finding sufficiently reliable criteria for the determination of the rock types occurring. The safest approach in such cases is only to delineate and number the various units and to give an accurate description of their photo-characteristics. The determination of the lithology is then left entirely to the field geologist.

The photogeology of areas of igneous and many metamorphic rocks is basically landform mapping, especially in forested areas. The limit to the amount of detail that can then be obtained is determined mainly by the minimum amount of the rock which has to occur for it to develop its characteristic topography. This minimum size depends on the relief, the terrain dissection, etc. and varies largely from one area to another. In areas of sedimentary rocks considerably smaller occurrences can still be correctly interpreted on the strength of their position in the geological structure, even if the characteristic terrain forms are insufficiently, or not at all, developed. More detailed information, therefore, can be generally expected in areas of sedimentary rocks, than in the case with igneous and metamorphic rocks. The scales of the photogeological maps will vary accordingly.

Small scale aerial photographs are the most suitable for this reconnaissance phase of the exploration and the modern super wide angle camera, allowing for photography even on 1:100,000 or 1:125,000 scales, is therefore an invaluable contribution to the rapid inventory of mineral resources. It is claimed, by some authors, that many important de-

tails cannot be distinguished at such small scales and that no satisfactory results can be expected from their interpretation. An answer to this objection, however, is that the amount of detail that can be obtained is not limited by the photo scale, but, as stated above, by the minimum size of a phenomenon needed for the development of the characteristic terrain forms. When interpreting small scale photographs it may be necessary to use the binoculars more frequently, but all necessary details can be derived from them provided that the image sharpness is excellent. Photo quality, therefore, is more critical than in the case of large scale photographs where the image of the various phenomena is larger. At present, because of the prime importance of superior photo quality, the climatic conditions prevailing in the area studied are the limiting factor for the minimum scale of aerial photography for geological purposes. In this respect infra-red emulsions, having a better haze penetration, are important particularly in humid tropical climates.

The advantage of small scale photography for geological reconnaissance is twofold. The larger area which it covers allows a better and quicker understanding of the relations between the various phenomena observed and of the patterns and alignments seen. The second advantage is in the lesser cost of the study and in the shorter time involved. This is due to the fact that both the cost and the speed of a photogeological survey, in much the same way as those of the photographic flight and the photogrammetric procedure, are approximately proportional to the number of photos required to cover the area. For the same purpose of covering a larger area per photograph, trimetrogon aerial photographs were extensively used during and shortly after the second world war, prior to the development of super wide angle photography. Notwithstanding the complications involved in the interpretation of oblique photos, this type of photography proved to be most useful for geological reconnaissance (Verstappen, 1960). This type of photography is at present rather obsolete, but for many remote areas it is often the only photo coverage existing. It should be stressed that even for a medium size project it pays to have new small scale photographs made instead of using an existing large scale coverage.

The field party plan will be based on the preliminary photogeological map. The geologist should take this map and the air photos into the field in order to check the map, to add his field observations and to make corrections if necessary. Improvements of the preliminary map are often possible by stereoscopic study of the air photos in the field camp during and after the investigations on the spot. It is therefore essential that there is an adequate liaison between the photo interpretation studies and the field work. This can best be achieved by having both aspects of the exploration, at least in part, carried out by the same persons. The final maps, compiled after completion of the field work, will serve as a basis for the selection of the more promising areas, where detailed exploration should be carried out.

Subsequent detailed exploration of selected areas.

The reconnaissance phase of exploration described in the foregoing paragraph can largely be avoided in countries where sufficient basic geological data is available. The areas of interest are then determined on the strength of this existing knowledge and the exploration immediately enters the more detailed phase. The photogeological approach to these more detailed studies is rather similar to that of the reconnaissance survey and the same stages, preliminary map-field work-final map, exist. It is often found convenient, however, to use a somewhat larger (medium) photo scale especially in areas where many small details, complicated structures or intricate joint patterns, are to be mapped. The larger number of photos is not a great disadvantage in these cases, because of the more limited size of the selected areas. Special emulsion types are often used with advantage. Much experience has recently been gained with colour aerial photographs for the detection of mineralized zones in arid and other poorly vegetated areas. In densely forested tropical zones their use is more limited and is especially related to exploration for lateritic ores. Research into the use of two layer emulsions and into the most appropriate sensitivity curve of the

emulsion to be selected for a certain project, is particularly promising. The light reflectance of the various rock types occurring in the area is measured by densitometer and the optimum wave length of maximum sensitivity of the emulsion is then chosen accordingly. The interpreter thus benefits fully from minor colour or grey tone differences.

Topography as an indication of the various rock types is also utilized to the full. Particular stress is laid on minor geomorphological features, such as the form of the cross-sections of the valleys and minute erosional features and other characteristics of the hill slopes. The quantitative aspect of photogeology becomes important in this part of the work, especially in oil exploration and other investigations in sedimentary rocks. The measurements include height differences, determination of dip and strike, computation of formational thickness, construction of structural contours, determination of offset along faults, etc. Somewhat more elaborate photogrammetric equipment is sometimes used for these detailed purposes, although most of the problems related to this kind of work can be solved by a good mirror stereoscope with binoculars and a stereometer. In areas of igneous and metamorphic rocks measurement of hill slopes, river gradients and drainage density is sometimes useful for more detailed work. The possibilities for detailed interpretation of the latter types of rock are usually very limited, however, if there is a dense vegetation cover and a larger percentage of the information has then to be obtained during the field survey. In all types of terrain more elaborate field investigations are necessary during the detailed mapping than during the reconnaissance phase of the work and geochemical and geophysical surveys also become more important.

The relation between photogeology and a geophysical survey needs some further consideration. A knowledge of the general geological trend of the area studied is most important for the planning of the geophysical survey, as the survey lines are usually located across the strike. The easiest way to obtain this information is by means of photogeology. The planning of ground geophysical surveys is, furthermore largely influenced by the trafficability of the terrain, information about which can likewise easily be derived from aerial photographs. It is thus evident that in unknown territories a photogeological reconnaissance should precede the geophysical survey so as to decide upon the applicability of this method and for the planning of the survey. During airborne geophysical surveys the actual survey lines are photographed during the flight thus allowing for an accurate location of the geophysical observations by comparing these photos with the overall airphoto coverage. Aerial photographs are thus useful during the planning and the execution of the geophysical survey. Much more important is the aid of photogeology in the correct interpretation of the geophysical data. It should be stressed that geophysical observation usually leaves room for more than one geological interpretation. "Blind" geophysical interpretation, without taking (photo)geological considerations into account, often leads to erroneous conclusions, so that both these methods should obviously go hand in hand.

Location of minerals.

The great variety of ore deposits, such as magmatic hydrothermal, sedimentary, ground water and weathering deposits, accounts for the fact that mineral deposits of economic importance can be expected in many different geological environments. Photogeology is an aid in the search for many of these deposits, but it should be stressed that the method has its distinct limitations. The best results are obtained, of course with mineral deposits which have a characteristic topographic expression. This is the case with a rather small percentage of ore deposits, such as those related to fractures, faults and veins. These linear features are often quite conspicuous from the air and thus can be mapped adequately. Veins often form ridges, the grey tones of which frequently indicate the acidity of the rock type occurring. Another example of topographic expression of lodes is that of weathered outcrops of ore bodies (gossan) which are sometimes easily detected from the air. Mineralization slumping, vegetation differences, etc. are other direct indications of the occurrence of ore bodies. In arid regions leached areas, different in tone from the un-

altered rocks, may be associated with uranium deposits. In the great majority of cases direct evidence for the occurrence of a mineral deposit is lacking, however, and the aerial photographic approach is then different. The photo geological map is used to obtain a detailed insight into the regional geology so as to decide in which areas the chances for mineral accumulation are best. Intrusive bodies, characterized by their irregular topography, are of particular importance in this connection. The contact zone with the surrounding sedimentaries, is usually the most likely location of the mineralization and in many cases mining activity is confined to these belts. Hydrothermal deposits are affiliated to certain host rocks whose permeability or other characteristics favour the formation of economic deposits.

Lateritic ores are another group of mineral occurrences which may well be detected by photogeological means. The laterites are formed on old weathering surfaces and they are characterized by poor vegetation, a usually flat and little dissected surface, and a reddish colour. Iron, manganese, aluminium, nickel, cobalt, etc. may occur as weathering deposits. Examples are the nickel and cobalt deposits of Brasil and New Guinea; and the bauxite of Jamaica.

Photogeology also has proved most valuable in the detection of placer deposits. Interesting results are obtained especially with alluvial deposits (river terraces, etc.) in gold exploration. The correct approach to this problem is to locate the igneous bodies from which the minerals supposedly originate and subsequently to concentrate the search along the rivers draining these source areas. The recent river alluvium and terraces are then mapped and particular attention is paid to outcropping in the river bed or valley of hard rock sills which may have affected the mineral deposition.

Oil exploration has made extensive use of photogeological methods since the 1930's and has given impetus to the development of geological photo interpretation. Qualitative interpretation of the geological structures such as faults, reefs, etc. and quantitative interpretation, such as measurement of strike and dip, structural contouring, etc. are important aspects of this field. Even in areas where the structures are covered by recent or subrecent deposits, the interpretation, based upon the orientation of drainage elements, linear features, etc., yielded remarkable results in some cases. The permeability of the various beds occurring can be estimated on the strength of minor erosional forms, drainage characteristics and vegetation. These indications are particularly useful for the estimation of reservoir.

Photogeological techniques also have been successfully used in relation to hydrogeological studies. Location of aquifers is an important aim in this connection and so is the mapping of fractures faults, dikes, etc. Apart from this geological aspect a knowledge of the climatological, hydrological and morphological situation is essential for the success of these studies so that the percentage of infiltration, surface runoff and evaporation may be estimated.

It is evident from the aforesaid that the technique of geological photo interpretation is a most important aid in all kinds of mineral exploration. It should be borne in mind, however, that it is only one of the tools of modern geology and that a thorough coordination of photogeological, geophysical, geochemical and conventional field investigations is indispensable in obtaining adequate results.

Literature.

VERSTAPPEN, H. Th. - 1960 - Photogeological reconnaissance using trimetrogon aerial photography. Proc. U.N. seminar on aerial survey methods and equipment, pp. 113 - 116.

[The body of the document contains several paragraphs of extremely faint, illegible text. The text appears to be a formal report or memorandum, possibly detailing a project or organizational structure. Due to the low contrast and quality of the scan, the specific words and sentences cannot be transcribed.]